

This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

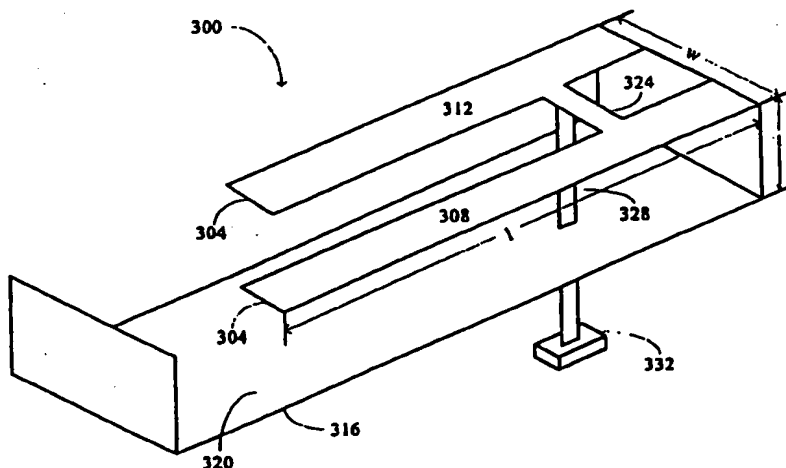
**As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.**



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : H01Q 9/04, 1/24, 5/00		A1	(11) International Publication Number: WO 98/44587
			(43) International Publication Date: 8 October 1998 (08.10.98)
(21) International Application Number: PCT/US98/05870		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).	
(22) International Filing Date: 25 March 1998 (25.03.98)			
(30) Priority Data: 08/825,543 31 March 1997 (31.03.97) US			
(71) Applicant: QUALCOMM INCORPORATED [US/US]; 6455 Lusk Boulevard, San Diego, CA 92121 (US).			
(72) Inventor: NGHIEM, David; 14806 Windcave Lane, Houston, TX 77040 (US).			
(74) Agents: MILLER, Russell, B. et al.; Qualcomm Incorporated, 6455 Lusk Boulevard, San Diego, CA 92121 (US).		<p>Published</p> <p><i>With international search report.</i></p> <p><i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	

(54) Title: INCREASED BANDWIDTH PATCH ANTENNA



(57) Abstract

An increased bandwidth patch antenna (300) which includes first and second arms (308, 312) spaced by an air gap. The first and second arms (308, 312) are electrically connected by a bridge (324). A ground plane (316), which is approximately parallel to the first and second arms (308, 312) is separated from the first and second arms (308, 312) by a dielectric substrate (320). In one embodiment of the present invention, the first arm (308) is a radiating arm and the second arm (312) is a tuning arm. By varying the length of the tuning arm, the bandwidth of the antenna is increased. The second arm (312), which also acts as a parasitic arm of the first arm (308), increases the gain of the antenna (300). A signal unit (332) is electrically coupled to the bridge (324). The signal unit (332) transmits and/or receives signals having a selected frequency band. The antenna (300) resonates at the selected frequency band.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TC	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	ME	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

INCREASED BANDWIDTH PATCH ANTENNA

BACKGROUND OF THE INVENTION

5

I. Field of the Invention

The present invention relates generally to antennas and, more specifically, to an increased bandwidth patch antenna.

10 II. Description of the Related Art

Antennas are an important component of wireless communication systems. Although antennas may seem to be available in numerous different shapes and sizes, they all operate according to the same basic principles of electromagnetics. An antenna is a structure associated with a
15 region of transition between a guided wave and a free-space wave, or vice versa. As a general principle, a guided wave traveling along a transmission line which opens out will radiate as a free-space wave, also known as an electromagnetic wave.

In recent years, with the rise in use of personal communication devices, such as PCS phones, cellular phones and other communication
20 devices, the need for small antennas that are suitable for use in personal communication devices has increased. An important factor to be considered in designing antennas for personal communication devices is the radiation pattern. In most applications, the communication device must be able to
25 communicate in all directions. Therefore, the device must receive and transmit signals effectively in all directions. Consequently, in personal communication devices, it is essential that the antenna has an omnidirectional radiation pattern. Furthermore, the antenna must be compact in size in order to be suitable in a personal communication device.

30 One antenna commonly used in personal communication devices is the whip antenna. There are, however, several disadvantages associated with the whip antenna. Often, the whip antenna is subject to damage by catching on things. Even when the whip antenna is designed to be retractable in order to prevent such damage, it consumes scarce interior
35 space. This results in less interior space being available for advanced features and circuits. Also, as personal communication devices such as cellular phones become smaller, the ability to use the whip antenna efficiently is being challenged.

Another antenna which may also be suitable for use in personal communication devices is the patch or microstrip antenna. The patch antenna was originally developed in the late 1960's for use with aircraft, missiles and other military applications requiring a thin or low-profile antenna. These applications required that the antenna neither disturb the aerodynamic flow nor protrude inwardly to disrupt the mechanical structure. The patch antenna satisfied these requirements.

The bandwidth of a patch antenna is proportional to the thickness of the dielectric substrate used. The thicker the substrate, the wider the antenna's bandwidth. In order to maintain desired bandwidth of personal communication devices, current patch antennas must have relatively thick substrates, which make them relatively bulky for personal communication devices. Since antennas in personal communication devices are required to be quite small in size, they would typically have thin substrates. Consequently, they would also have narrow bandwidth. Unfortunately, a narrow bandwidth restricts the utility of the antenna to a narrow frequency band. An increased bandwidth would allow personal communication devices to operate over a wider frequency band.

20

SUMMARY OF THE INVENTION

The present invention is directed to an increased bandwidth patch antenna. According to the present invention, the patch antenna includes a conductor plate having first and second arms. The first and second arms are spaced by an air gap. A bridge connects the first and second arms. A ground plane which is approximately parallel to the conductor plate is separated from the conductor plate by a dielectric substrate.

According to one embodiment of the present invention, the first arm is a radiating arm and the second arm is a tuning arm. The length of the radiating arm is set in relation to the wavelength λ associated with the resonant frequency f_0 . Commonly used lengths are λ , $\lambda/2$ and $\lambda/4$, although other lengths are possible. The length of the second arm is longer or shorter than that of the first arm. By varying the length of the second arm, the bandwidth of the antenna is increased. Furthermore, the second arm acts as a parasitic arm of the first arm, which increases the gain of the antenna. The parasitic arm also increases the bandwidth of the antenna by increasing its overall volume.

In another embodiment of the present invention, dual band operation is achieved by exciting the second arm by a second frequency band

while the first arm is also being excited by a first frequency band. In this embodiment, the first and second arms are each excited with separate frequency bands. The first arm acts as a first active radiator and the second arm acts as a first tuning arm. Likewise, the second arm acts as a second active radiator and the first arm acts as a second tuning arm. The length of the first arm is set in relation to the first frequency band, while the length of the second arm is set in relation to the second frequency band.

One advantage of the present invention is that it provides an increased bandwidth and increased gain over conventional patch antennas. Another advantage of the present invention is that it provides dual frequency band operation.

Further features and advantages of the invention, as well as the structure and operation of various embodiments of the invention, are described in detail below with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements. The drawing in which an element first appears is indicated by the leftmost digit(s) in the reference number. The present invention will be described with reference to the accompanying drawings, wherein:

- FIG. 1 illustrates a portable telephone utilizing the present invention;
- FIG. 2 illustrates a conventional quarter-wave patch antenna;
- FIG. 3 illustrates an increased bandwidth quarter-wave patch antenna in accordance with the present invention; and
- FIG. 4 depicts a computer simulated frequency response of the increased bandwidth quarter-wave patch antenna of FIG. 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

1. Overview and Discussion of the Invention

As discussed earlier, the patch antenna was originally developed in the late 1960's for use with aircraft, missiles and other military applications requiring a thin or low-profile antenna. These applications required that the antenna neither disturb the aerodynamic flow nor protrude inwardly to

disrupt the mechanical structure. The patch antenna satisfied these requirements.

These characteristics that make the patch antenna suitable for use in aircraft and missiles also make it suitable for use in hand-held and mobile personal communication devices. For example, the patch antenna can be built on the top surface of a personal communication device such as a cellular phone, or to a surface of a vehicle carrying a personal communication device, or built or mounted on some other device. This means that it can be manufactured with increased automation and decreased manual labor of installation. This decreases costs and increases reliability. Also, unlike the whip antenna, the patch antenna is less susceptible to damage by catching on things because it has a very low profile. Furthermore, since the patch antenna can be built on the personal communication device's top surface, it will not consume interior space which is needed for advanced features and circuits.

In addition, the patch antenna possesses other characteristics which make it suitable in personal communication devices. For example, the quarter-wave patch antenna, which is a version of a patch antenna, radiates an omnidirectional pattern into space above the ground plane, which makes it suitable in personal communication devices. Also at the frequency band over which the personal communication devices operate, the length of the quarter-wave patch antenna is quite short.

The bandwidth of the patch antenna is proportional to the thickness of the dielectric substrate used. The thicker the substrate, the wider the antenna's bandwidth. In order to maintain desired bandwidth of personal communication devices, current patch antennas must have relatively thick substrates, which make them relatively bulky for personal communication devices. Since antennas in personal communication devices are required to be quite small in size, they typically have thin substrates. Consequently, they have narrow bandwidth. Unfortunately, a narrow bandwidth restricts the utility of the antenna to a narrow frequency band. An increased bandwidth would allow the personal communication devices to operate over a wider frequency band.

The present invention provides a solution to this problem. The present invention allows a patch antenna to have increased bandwidth without requiring an increase in the thickness of its dielectric substrate. This allows the patch antenna to have a relatively small overall size, which makes it suitable in personal communication devices.

According to the present invention, the patch antenna includes a conductor plate having first and second arms. The first and second arms are approximately planar to each other and are spaced by an air gap. A bridge connects the first and second arms. A ground plane which is approximately parallel to the conductor plate is separated from the conductor plate by a dielectric substrate.

In one embodiment of the present invention, the first arm is a radiating arm and the second arm is a tuning arm. By varying the length of the tuning arm, the bandwidth of the antenna is increased. The second arm acts as a parasitic arm of the first arm, which increases the gain of the antenna. The parasitic arm also increases the bandwidth of the antenna by increasing the overall volume of the antenna.

The length of the radiating arm is set in relation to the wavelength λ associated with the resonant frequency f_0 . Commonly used lengths are λ , $\lambda/2$ and $\lambda/4$, although other lengths are possible.

The present invention is described in connection with a patch antenna having a length of $\lambda/4$, also known as a quarter-wave patch antenna. Although the present invention is described in connection with the quarter-wave patch antenna, its utility is not restricted merely to the quarter-wave patch antenna. In fact, those skilled in the art will recognize that the present invention may be utilized in a patch antenna having any length, such as a full-wave, half-wave or $n\lambda/4$, where n is an integer.

2. Example Environment

Before describing the invention in detail, it is useful to show an example environment in which the invention can be implemented. In a broad sense, the invention can be implemented in any personal communication device. One such environment is a portable telephone, such as that used for cellular, PCS or other commercial service.

FIG. 1 illustrates a portable phone 100. Specifically, FIG. 1 includes a patch antenna 104, a speaker 108, a microphone 112, a display 116 and a keyboard 120.

Antenna 104 is built into the top surface of portable phone 100. Since antenna 104 has a very low profile, it is not subject to damage by catching on things. Also, unlike a retractable whip antenna, antenna 104 does not consume interior space in portable phone 100. This results in more interior space being available for advanced features and electronics.

The present invention is described in terms of this example environment. Some specific application examples are discussed in terms of cellular and PCS frequencies. Description in these terms is provided for convenience only. It is not intended that the invention be limited to application in this example environment. In fact, after reading the following description, it will become readily apparent to a person skilled in the relevant art how to implement the invention in alternative environments, such as, for example, in automobiles, truck-trailer, other types of vehicles and hand-held devices.

3. A Conventional Quarter-Wave Patch Antenna

FIG. 2 illustrates a conventional quarter-wave patch antenna 200. Specifically, FIG. 2 includes a conductor plate 204, a dielectric substrate 208, a ground plane 212 and a signal unit 216.

The length ℓ of antenna 200 determines its resonant frequency. As a general rule, quarter-wave patch antenna 200 having a length ℓ resonates at a frequency of $c/(4\ell)$, where c is the speed of light. Thus, the resonant frequency of quarter-wave patch antenna 200 can be selected by selecting ℓ . At or near the resonant frequency, quarter-wave patch antenna 200 radiates most effectively. Consequently, quarter wave patch antenna 200 is designed to operate at or near the resonant frequency. For example, at an operating frequency of approximately 1.9 GHz (PCS frequency), the wavelength λ of the radio signal is approximately 7 inches. Thus, the length of antenna 200 is approximately 1.75 inches.

The height of antenna 200 is determined by the thickness t of dielectric substrate 208. The selected value of t is based on the bandwidth over which antenna 200 must operate. In addition, there are other factors which impact the value of t . If t is too large, the overall size of antenna 200 becomes too large, which makes antenna 200 undesirable for personal communication devices. Also, if t is too large, surface wave modes are excited which degrades the performance of antenna 200. If, on the other hand, t is too small, conductor plate 204 is too close to ground plane 212. This causes the surface current induced in ground plane 212 to be too strong which causes high ohmic loss. As a result, the efficiency of antenna 200 is degraded. In practice, the thickness t of dielectric substrate 208 is held at less than or equal to one-tenth of the wavelength in dielectric substrate 208 or $\lambda_g/10$, where $\lambda_g = \lambda_0/\sqrt{\epsilon_{eff}}$, λ_0 is the wavelength in air and ϵ_{eff} is the dielectric constant in dielectric substrate 208.

The width w of antenna 200 should be less than a wavelength so that higher-order modes will not be excited. Moreover, in order to make the antenna suitable for a personal communication device, the width is usually kept relatively small.

5 Ground plane 212 is typically made of a conductive material such as gold, silver, copper, aluminum or brass. Other conductive materials may also be used. Ground plane 212 is separated from conductor plate 204 by dielectric substrate 208 and is approximately parallel to conductor plate 204. One end of conductor plate 216 is electrically connected to ground plane 212.

10 A probe is electrically connected to conductor plate 212. The probe, which may be a coaxial cable, passes through ground plane 212 and meets conductor plate 204 near an end. The probe couples signal unit 216 to conductor plate 204. Signal unit 216 provides a signal of a selected frequency band to conductor plate 204, which creates a surface current in conductor
15 plate 204. The density of the surface current is high near the region of conductor plate 204 where the probe meets conductor plate 204 and decreases gradually along the length of conductor plate 204 in the direction away from the point where the probe meets conductor plate 204. In fact, the surface current is concentrated in the first half of conductor plate 204 and is
20 negligible in the second half.

As discussed earlier, an increase in bandwidth of the quarter-wave patch antenna is desired. An increase in bandwidth of the antenna would enable a personal communication device to operate at a wider range of
25 frequency.

4. Increased Bandwidth Patch Antenna

The present invention achieves an increase in bandwidth over
30 conventional patch antennas while retaining characteristics that are desirable for personal communication devices. The present invention is now described with reference to FIG. 3. FIG. 3 illustrates an increased bandwidth patch antenna 300 in accordance with one embodiment of the present invention. The embodiment illustrated in FIG. 3 is a quarter-wave
35 patch antenna. Specifically, the embodiment illustrated in FIG. 3 comprises a conductor plate 304 having first and second arms 308 and 312, a ground plane 316, a dielectric substrate 320, a bridge 324, a probe 328 and a signal unit 332.

Note that signal unit 332 is used herein to refer to the functionality provided by a signal source and/or a signal receiver. Whether signal unit

332 provides one or both of these functionalities depends upon how antenna 300 is configured to operate. Antenna 300 described herein could, for example, be configured to operate solely as a transmitter, in which case signal unit 332 operates as a signal source. Alternatively, signal unit 332
5 operates as a signal receiver when antenna 300 is configured to operate solely as a receiver. Signal unit 332 provides both functionalities (e.g., a transceiver) when antenna 300 is configured to operate as both a transmitter and receiver. Those skilled in the art will recognize the various ways in which the functionality of generating and/or receiving signals might be
10 implemented.

Conductor plate 304 is comprised of first and second arms 308 and 312. First arm 308 is a radiating arm (a radiating element) and second arm 312 is a tuning arm (a tuning element). By varying the length of second arm 312, the bandwidth of antenna 300 is increased. Also, by varying the length of
15 second arm 312, the input impedance of antenna 300 can be matched with an input circuit. Thus, second arm 312 provides a convenient way to increase the bandwidth and match the input impedance of patch antenna 300 with an input circuit. This allows the added flexibility of being able to closely match the impedance of antenna 300 with particular circuits.

20 Furthermore, second arm 312 acts as a parasitic arm of first arm 308 due to a field effect. By acting as the parasitic arm of first arm 308, second arm 312 increases the gain of antenna 300. The parasitic arm also increases the bandwidth of antenna 300 by increasing the overall volume of antenna 300.

25 Because first arm 308 is the radiating arm of quarter-wave patch antenna 300, its length is set at approximately a fourth of a wavelength. Depending on a particular application, the length of second arm 312 may be longer or shorter than that of first arm 308.

First and second arms 308 and 312 are approximately planar to each other and are separated by an air gap of a distance d . If d is too small, first
30 and second arms 308 and 312 are too close to each other, and there is excessive coupling between first and second arms 308 and 312. As d approaches zero, first and second arms 308 and 312 act like a single antenna. This prevents second arm 312 from functioning as a tuning arm as well as a
35 parasitic arm of first arm 308. On the other hand, if d is too large, coupling between first and second arms 308 and 312 is negligible. Consequently, second arm 312 ceases to be a parasitic arm. In practice, d is kept small because it makes the antenna small in size which is desirable in a personal communication device.

Ground plane 316 is made of a conductive material such as, for example, aluminum, copper, gold, silver or brass. Ground plane 316 is separated from conductor plate 304 by dielectric substrate 320 and is approximately parallel to conductor plate 304. One end of conductor plate 304 is electrically connected to ground plane 316. The overall length of antenna 300 can be reduced in size by bending a portion of ground plane 316 near the edge at a 90 degree angle.

In one embodiment of the present invention, air is selected as dielectric substrate 320. Air has a dielectric constant of approximately 1 and it produces a negligible dielectric loss. Because the personal communication devices are typically powered by batteries that have limited energy storage capability, it is important to reduce dielectric loss in antenna 300. Thus, air is selected as a preferred dielectric substrate because it produces a negligible dielectric loss.

Probe 328 couples signal unit 332 to bridge 324. Signal unit 332 provides antenna 300 with a signal having a selected frequency band. In a PCS phone, the frequency band is generally 1.85-1.99 GHz. In a cellular phone, the frequency band is generally 824-894 MHz. First arm 308 (the radiating arm) receives the signal because it is sized appropriately for the selected frequency band, and it resonates at the selected frequency band.

The height of antenna 300 is determined by the thickness t of dielectric substrate 320. As before, if t is too small, conductor plate 304 is too close to ground plane 316. As a result, a surface current induced in ground plane 316 tends to be very strong which results in high ohmic loss in ground plane 316. Consequently, the efficiency of antenna 300 is degraded. If on the other hand, t is too large, surface wave modes are excited which degrades the antenna's performance.

Also, the bandwidth of antenna 300 is proportional to the thickness t of dielectric substrate 320. The thicker the substrate, the wider the antenna's bandwidth. While increasing t may seem like an easy way to increase the bandwidth of antenna 300, practical considerations dictate that t be small. A small t allows antenna 300 to have a low profile, which makes it suitable for portable devices such as a personal communication device. Thus, antenna designers have in the past reluctantly settled for a narrow bandwidth in order to make the antenna smaller in size.

The present invention allows increased bandwidth without increasing t . As noted before, in the present invention, the bandwidth of antenna 300 can be increased by adjusting the length of second arm 312 (the tuning arm). Also, as noted before, second arm 312 acts as a parasitic arm

which increases the overall volume of antenna 300. Consequently, the bandwidth of antenna 300 is increased even further.

5 Additionally, the present invention allows dual frequency band operation when second arm 312 is excited with a second frequency band while first arm 308 is also being excited by a first frequency band. In this mode, first and second arms 308 and 312 are each excited with separate frequency bands. First arm 308 acts as a first active radiator and second arm 312 acts as a first tuning arm. Likewise, second arm 312 acts as a second active radiator and first arm 308 acts as a second tuning arm.

10 The length of first arm 308 is approximately a fourth of a wavelength of the first frequency. Likewise, the length of second arm 312 is approximately a fourth of a wavelength of the second frequency. Thus, the lengths of first and second arms 308 and 312 are sized appropriately for the first and second frequency bands, respectively.

15 The length of second arm 312 may be longer or shorter than the length of first arm 308. If, for instance, the second frequency band is higher than the first frequency band, the length of second arm 312 is shorter than the length of first arm 308. If, on the other hand, the first frequency band is higher than the second frequency band, the length of second arm 312 is longer than the length of first arm 308.

20 Bridge 324 electrically connects probe 328 to first and second arms 308 and 312. Bridge 324, thus, provides a convenient way to connect the signal source to first and second arms 308 and 312.

25 Signal unit 332 provides antenna 300 with two signals: a first signal having the first frequency band, and a second signal having the second frequency band. In operation, first arm 308 receives the first signal and resonates at the first frequency band. First arm 308 resonates at the first frequency band because it is sized appropriately (a fourth of a wavelength of the first frequency). Likewise, second arm 312 resonates at the second frequency band because it is sized appropriately for the second frequency band.

30 As noted before, the present invention allows antenna 300 to have a wider bandwidth than a conventional quarter-wave patch antenna of the same volume. For example, a conventional quarter-wave patch antenna having a length of 1.3 inches, a thickness of .25 inches and a width of 0.5 inches has a 2% bandwidth. In contrast, the present invention allows antenna 300 having generally the same dimensions to have a 7% bandwidth.

In one example embodiment of the present invention, antenna 300 has the following dimensions: the length of first arm 308 is 1.30 inches; the length of second arm 312 is 1.10 inches; the overall width w is 0.5 inches; the thickness t is 0.25 inches; the length of ground plane 316 is 2.0 inches with a portion of the length (0.25 inches) being bent at a right angle; and the air gap d is 0.2 inches. First arm 308 is the radiating arm and second arm 312 is the tuning arm. FIG. 4 depicts a computer simulated frequency response of the example embodiment. Antenna 300 has a 10 dB response at 1.9 GHz and 2.04 GHz (PCS frequencies). Thus, antenna 300 has a 7% bandwidth.

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

CLAIMS

1. A patch antenna, comprising:
 - 2 a radiating arm and a tuning arm, said radiating arm being spaced from said tuning arm by an air gap, said radiating arm having a length of
 - 4 approximately $n\lambda/4$, said tuning arm having a length different from that of said radiating arm, said radiating arm being electrically connected to said
 - 6 tuning arm; and
 - 8 a ground plane separated from said radiating arm and said tuning arm by a dielectric substrate;
 - 10 wherein the bandwidth of said patch antenna is determined by the length of said tuning arm.
2. The patch antenna according to claim 1, wherein said ground plane is substantially parallel to said radiating arm and said tuning arm.
3. The patch antenna according to claim 1, wherein said radiating arm and said tuning arm are electrically connected by a bridge.
4. The patch antenna according to claim 1, wherein said ground plane is electrically connected to one end of said radiating arm and to one end of said tuning arm.
5. The patch antenna according to claim 1, wherein a portion of said ground plane is bent at a 90 degree angle to reduce the overall length of said patch antenna.
6. The patch antenna according to claim 1, wherein $n = 1$.
7. The patch antenna according to claim 1, wherein n is an integer.
8. The patch antenna according to claim 1, wherein the thickness of said dielectric substrate is less than or equal to $\lambda_g/10$.
9. The patch antenna according to claim 1, wherein said radiating arm and said tuning arm are substantially parallel to one another.

10. A patch antenna, comprising:
- 2 a radiating arm and a tuning arm, said radiating arm being spaced
from said tuning arm by an air gap, said radiating arm having a length of
4 approximately $n\lambda/4$, said tuning arm having a length different from that of
said radiating arm, said radiating arm and said tuning arm being electrically
6 connected by a bridge;
a ground plane separated from said radiating arm and said tuning
8 arm by a dielectric substrate; and
a signal unit electrically coupled to said bridge, said signal unit
10 providing said patch antenna with a signal having a first frequency band;
wherein, the bandwidth of said patch antenna is determined by the
12 length of said tuning arm.
11. The patch antenna according to claim 9, wherein said ground
2 plane is substantially parallel to said radiating arm and said tuning arm.
12. The patch antenna according to claim 9, wherein the length of
2 said ground plane is longer than the length of said radiating arm.
13. The patch antenna according to claim 9, wherein said ground
2 plane is electrically connected to one end of said radiating arm and to one
end of said tuning arm.
14. The patch antenna according to claim 9, wherein a portion of
2 said ground plane is bent at a 90 degree angle to reduce the overall length of
said patch antenna.
15. The patch antenna according to claim 9, wherein $n = 1$.
- 2 16. The patch antenna according to claim 9, wherein n is an
integer.
17. The patch antenna according to claim 9, wherein the thickness
2 of said dielectric substrate is less than or equal to $\lambda_g/10$.
18. The patch antenna according to claim 9, wherein said radiating
2 arm and said tuning arm are substantially parallel to one another.

19. A patch antenna, comprising:
2 a first arm and a second arm, said first arm being spaced from said
second arm by an air gap, said second arm having a length different from
4 that of said first arm, said first arm and said second arm being electrically
connected by a bridge;
6 a ground plane separated from said first arm and said second arm by a
dielectric substrate; and
8 a signal unit electrically coupled to said bridge, said signal unit
providing said patch antenna with a first and a second signal, said first signal
10 having a first frequency band and said second signal having a second
frequency band,
12 wherein, said first arm resonates at said first frequency band and said
second arm resonates at said second frequency band.

20. The patch antenna according to claim 17, wherein said ground
2 plane is substantially parallel to said first and second arms.

21. The patch antenna according to claim 17, wherein said ground
2 plane is electrically connected to one end of said radiating arm and to one
end of said tuning arm.

22. The patch antenna according to claim 17, wherein a portion of
2 said ground plane is bent at a 90 degree angle to reduce the overall length of
said patch antenna.

23. The patch antenna according to claim 17, wherein the thickness
2 of said dielectric substrate is less than or equal to $\lambda_g/10$.

24. The patch antenna according to claim 17, wherein said first arm
2 and said second arm are substantially parallel to one another.

25. A patch antenna, comprising:
2 a radiating means for radiating a signal;
a tuning means, spaced by an air gap from said radiating means, for
4 increasing the bandwidth of said patch antenna, said tuning means being
electrically connected to said radiating means; and
6 a ground plane separated from said radiating means and said tuning
means by a dielectric substrate.

26. The patch antenna according to claim 23, wherein said
2 radiating means is electrically connected to said tuning means by a bridge.

27. The patch antenna according to claim 24, wherein a signal
2 means is electrically coupled to said bridge.

1/4

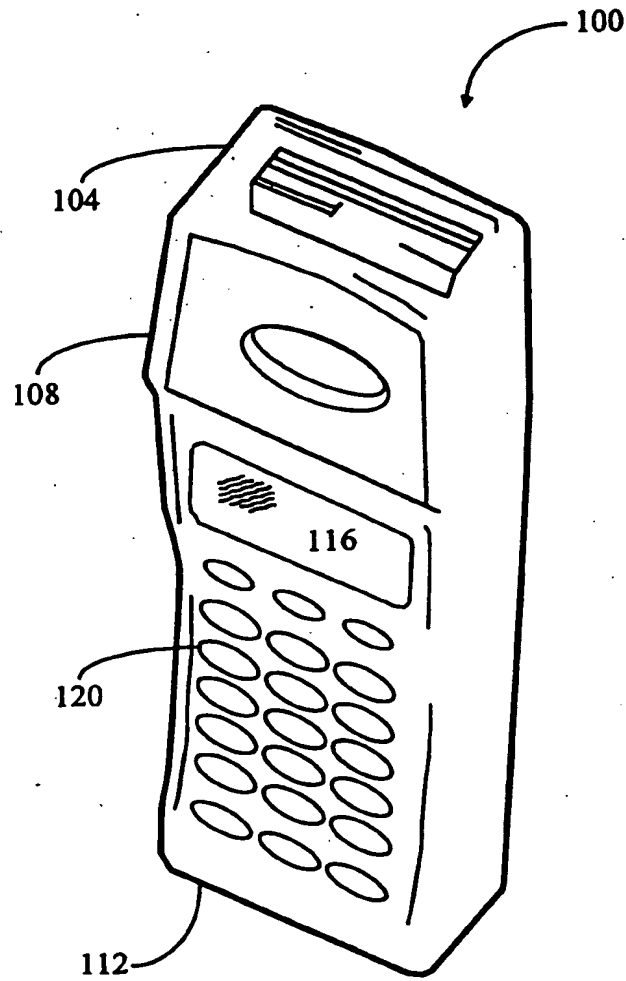


FIG. 1

2/4

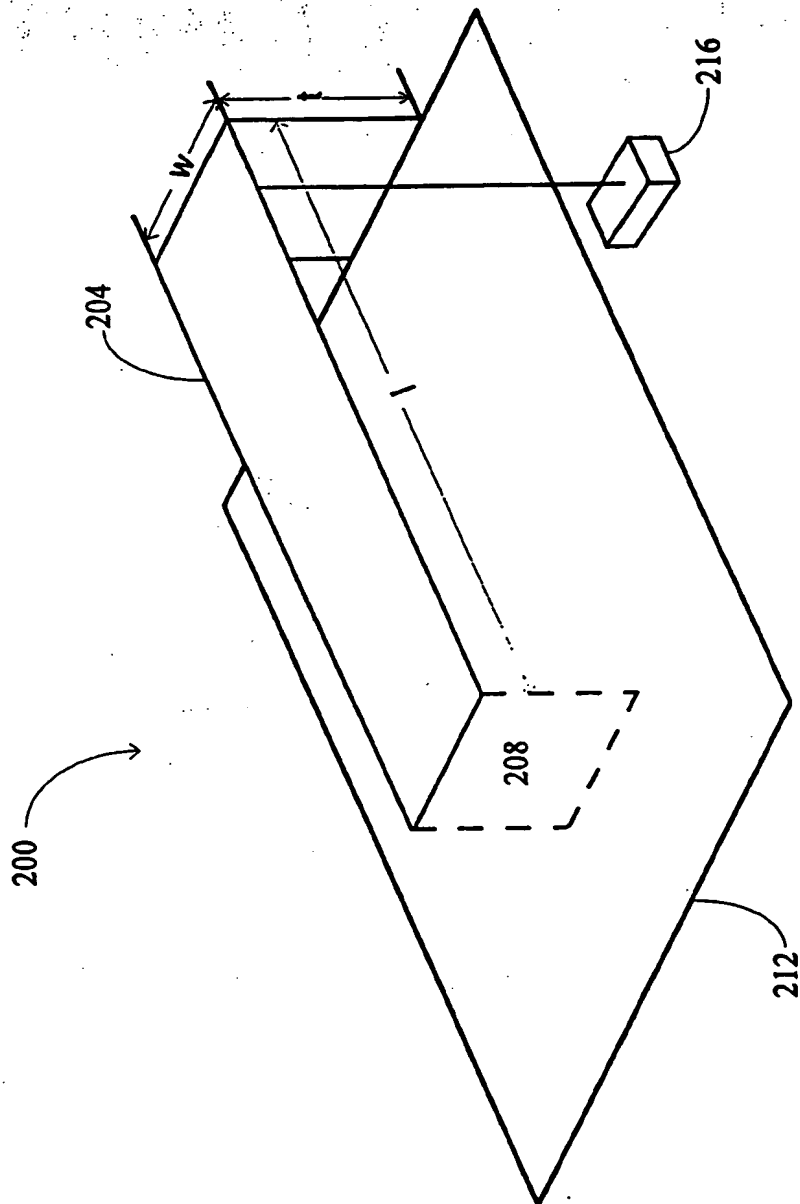


FIG. 2

3/4

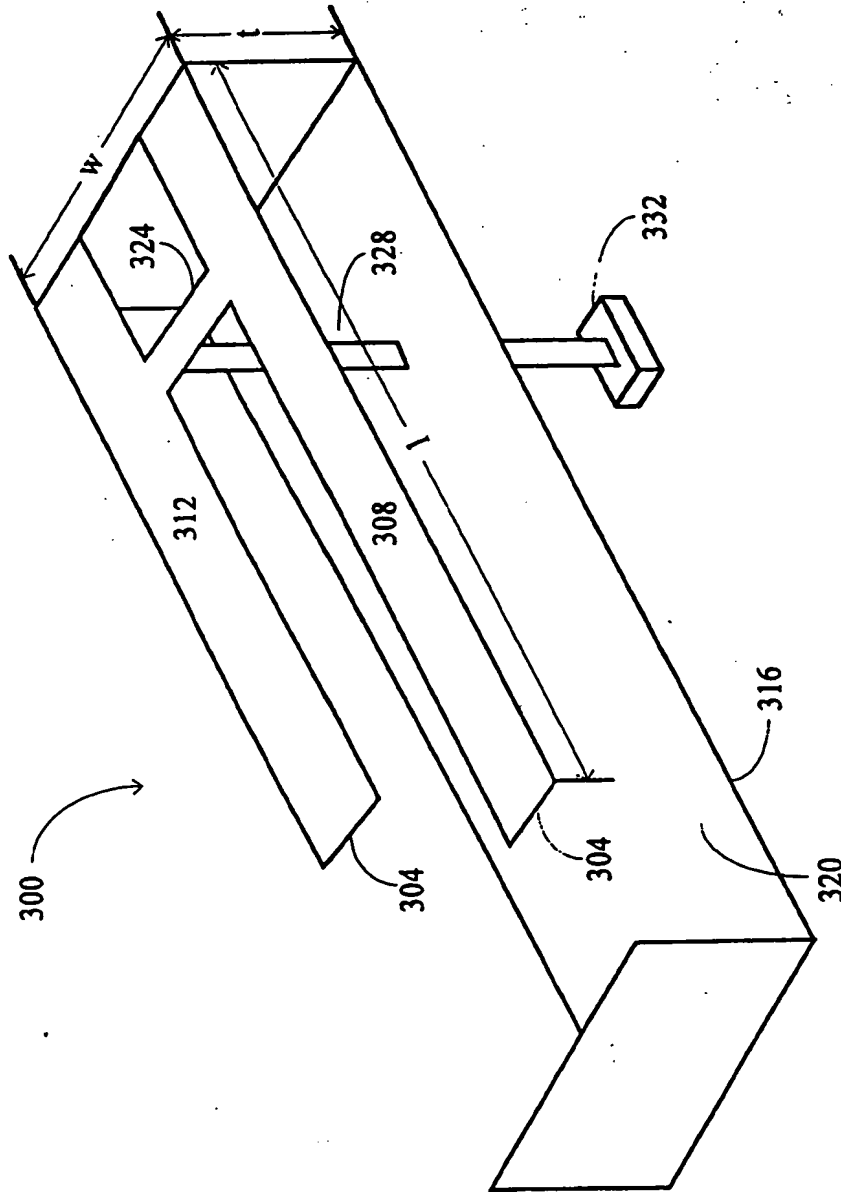


FIG. 3

4/4

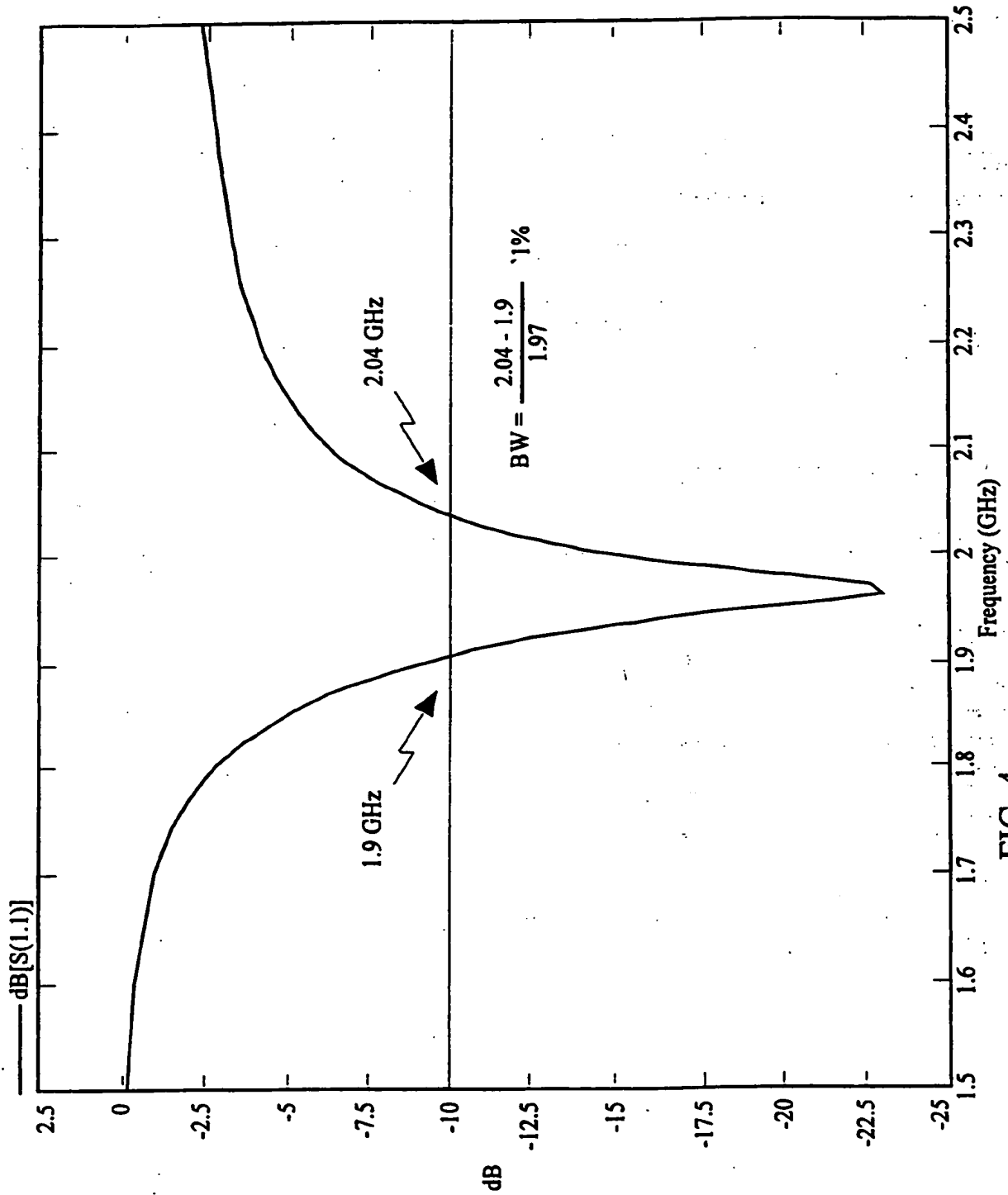


FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/05870

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H0109/04 H0101/24 H0105/00

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	AU 55898 73 A (ANTENNA ENG AUSTRALIA) 21 November 1974 see the whole document	1-27
X	EP 0 604 338 A (FRANCE TELECOM) 29 June 1994 see column 6, line 57 - column 9, line 31; figures 3,7,11	1,2,4-9
X	DE 195 12 003 A (FRANCE TELECOM) 5 October 1995 see column 2, line 59 - column 3, line 5; figures 2,6-12	1,2,4-9
X	WO 91 02386 A (SIEMENS AG OESTERREICH ;SIEMENS AG (DE)) 21 February 1991 see page 6, line 31 - page 7, line 8 see page 7, line 21-28; figures 1,3-5	1,2,4-9
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

7 July 1998

Date of mailing of the international search report

29/07/1998

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Van Dooren, G

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/05870

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 177 362 A (NIPPON ELECTRIC CO ;NAOHISA GOTO (JP)) 9 Apr 11 1986 see page 11, line 19 - page 18, line 9; figure 6	1
A		5, 10, 14, 19, 22, 25
X	<p>FUHL J ET-AL: "INTERNAL BROADBAND ANTENNA FOR HAND-HELD TERMINALS WITH REDUCED GAIN IN THE DIRECTION OF THE USER'S HEAD" PROCEEDINGS OF THE VEHICULAR TECHNOLOGY CONFERENCE, CHICAGO, JULY 25 - 28, 1995, vol. VOL. 2, no. CONF. 45, 25 July 1995, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 848-852, XP000551654 see sections III-V see figures 1,4</p>	1
X	<p>SABATIER C: "2 GHZ COMPACT ANTENNAS ON HANDSETS" IEEE ANTENNAS AND PROPAGATION SOCIETY INTERNATIONAL SYMPOSIUM DIGEST, NEWPORT BEACH, JUNE 18 - 23, 1995 HELD IN CONJUNCTION WITH THE USNC/URSI NATIONAL RADIO SCIENCE MEETI, vol. VOL. 2, 18 June 1995, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 1136-1139, XP000588503 see the whole document</p>	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

In International Application No

PCT/US 98/05870

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
AU 5589873 A	21-11-1974	NONE	
EP 0604338 A	29-06-1994	FR 2699740 A DE 69317235 D	24-06-1994 09-04-1998
DE 19512003 A	05-10-1995	FR 2718292 A GB 2288284 A,B	06-10-1995 11-10-1995
WO 9102386 A	21-02-1991	AT 393054 B AT 112421 T DE 59007355 D EP 0484454 A JP 5500889 T US 5365246 A	12-08-1991 15-10-1994 03-11-1994 13-05-1992 18-02-1993 15-11-1994
EP 0177362 A	09-04-1986	JP 1785236 C JP 4071368 B JP 61087434 A AU 574630 B AU 4829985 A CA 1235752 A DE 3585585 A US 4641366 A	31-08-1993 13-11-1992 02-05-1986 07-07-1988 10-04-1986 26-04-1988 16-04-1992 03-02-1987